THE VOLCANOES AND ROCKS OF PANTELLERIA

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PART II

PETROGRAPHY[1]

The rocks of Pantelleria have been described in modern times only by Foerstner[2] and Rosenbusch.[3] Most of the names assigned by Foerstner are not in accord with present nomenclature or the rock characters. His "phonolites" contain so much silica that no nephelite could form, they being quartz-bearing instead, and his "andesites" contain no soda-lime feldspar, the triclinic feldspar present being a soda-microcline. His "liparites" may best be considered as pantellerites—a group discovered by him, and with well-marked characters, though his synonym, "dacite-liparite," is open to the same criticism as his "andesite." His basalts are normal feldspathic ones.

Rosenbusch describes some of the rocks in detail, while others are only mentioned. He accepts Foerstner's group of pantellerites, to which he refers his "liparites." He remarks on the anomalous character of the "phonolites" and "andesites," but retains Foerstner's names, the highly siliceous composition of the former and the peralkalic character of the latter not being taken into consideration.

The following rocks, named according to the Qualitative System, occur on Pantelleria, their positions in the Quantitative System being also given. They will be described in this order.

[1] The specimens collected by me are supplemented by a set collected by Mr. F. H. Butler of London in 1891, and obtained from him in 1897.

[2] H. Foerstner, *Boll. Com. Geol. Ital.*, 1881, pp. 533–38.

[3] H. Rosenbusch, *Mikr., Phys.*, Vierte Aufl., II, No. 2 (1908), pp. 839, 851, 926, 967, 1039, 1115, 1357. A few very brief descriptions are given by G. T. Prior (*Min. Mag.*, XIII [1903], 254).

Rock Names	Subrangs
Soda trachyte	Kallerudose, I. 4. 1. 4 Nordmarkose, I. 5. 1. 4
Pantelleritic trachyte	Grorudose, II. 4. 1. 3
Comendite	Grorudose, II. 4. 1. 3
Aegirite pantellerite	Grorudose, II. 4. 1. 3
Hyalopantellerite	Varingose, II. 3. 1. 3 Grorudose, II. 4. 1. 3
Basalt	Camptonose, III. 5. 3. 4

SODA TRACHYTE, GIBELÉ TYPE (GIBELAL NORDMARKOSE)

Occurrence.—Lavas of this type, the "andesites" of Foerstner and Rosenbusch, constitute the mass of Montagna Grande and Monte Gibelé, covered in places with beds of pumice or flows of hyalopantellerite. The sheets of lava which make up the scarps of Montagna Grande are massive and often show a roughly columnar structure, while those of Monte Gibelé are, in general, less massive and compact. Along Costa Zichidi they form the uppermost flows, extending westward to the sea near Porto Scauri. Trachyte tuffs do not seem to occur.

Megascopic characters.—Lavas of this type vary from very compact forms to those which are somewhat vesicular. Strictly scoriaceous flows were not observed and even those which are vesicular show streaks of compact rock. The color is a light gray, the feel is rough and the texture highly porphyritic.

Practically the only phenocrysts visible are of alkali feldspar, which form from 25 to 30 per cent of the rock, so that the type is dopatic. These are tabular, highly cleavable, with glistening surfaces, colorless and transparent, and are 1 to 2 cm. in diameter. A few small (1–2 mm.) phenocrysts of black augite are present, but they are so few in number and so inconspicuous as to be negligible. The groundmass is a light ash gray and almost aphanitic, though the lens reveals the presence of light and fewer dark particles, and it is clearly phanerocrystalline. In megascopic habit these rocks resemble so closely some from Ischia and the Phlegrean fields as to be almost indistinguishable from them.

Microscopic characters (*Fig. 6*).—The microscopic characters of this type from Pantelleria have been described by Rosen-

busch,[1] with whose observations my own coincide in nearly all particulars.

The most abundant and largest phenocrysts are of soda-microcline, in thick tables, parallel to *b* (010), or in stout prisms elongated parallel to the vertical axis, either euhedral or subhedral, and often fragmentary. Some of these show a microperthitic structure in very fine lamellae, which resembles the lamellar twinning of the soda-lime feldspars and accounts for Foerstner's designation of "andesite." Typical microcline grating-structure is rare in my specimens, but Carlsbad twinning occurs. In many cases the feldspar phenocrysts are free from inclusions, but in others, especially from Monte Gibelé, there are inclusions of augite (which is often poikilitic and extinguishes simultaneously in isolated patches).

A few small phenocrysts of augite are present. They are mostly stout subhedral prisms, either colorless or light greenish and non-pleochroic. Aegirite-augite is either wanting or very rare, but occurs in the rocks from Costa Zichidi and its neighborhood. No phenocrysts of either hornblende or biotite are present, and small phenocrysts of olivine were only rarely seen, though Rosenbusch notes this mineral as an almost constant phenocrystic accessory. Small irregular grains of magnetite are fairly constant, but always in small amount, this type and the basalts being the only rocks of the island in which it occurs.

The typical groundmass is holocrystalline, but a little glass may be present occasionally, and some of the Gibelé lavas are quite vitrophyric. Soda-microcline makes up the greater part, either in short, small laths or anhedra, both being present in the same specimen. A flow texture is more or less well developed, though this seldom assumes a typically trachytic fabric.

The mafic[2] minerals in the groundmass are pyroxene and hornblende. The former is a colorless augite, less often greenish and aegiritic, in prisms or more abundant anhedra. No hypersthene

[1] H. Rosenbusch, *Mikr. Phys.*, II, No. 2 (1908), p. 1115; on p. 926 he speaks of them as trachytes.

[2] Equivalent to ferromagnesian; cf. Cross, Iddings, Pirsson, and Washington, *Jour. Geol.*, XX (1912), 560.

FIG. 6.—Trachyte, Montagna Grande. × 20

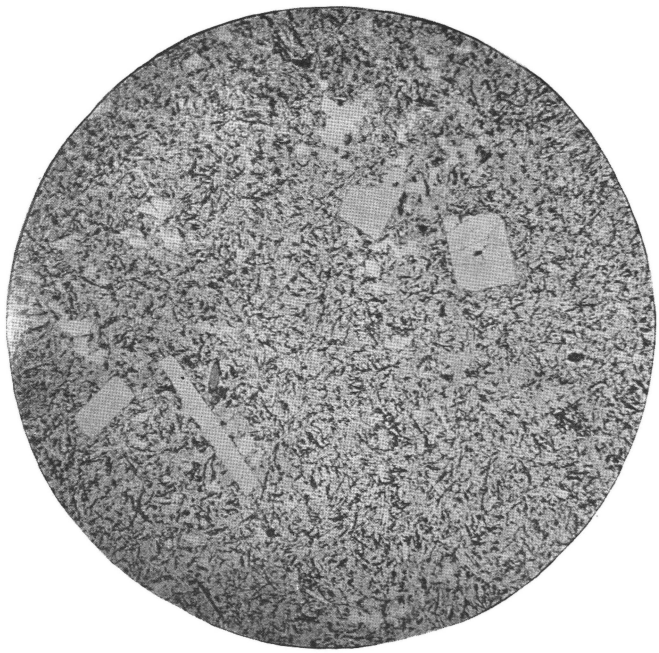

FIG. 7.—Pantelleritic trachyte, Costa Zeneti. × 20

could be identified by me. The hornblende is a very dark chestnut brown, intensely pleochroic, in small prisms and anhedra, which show no cleavage. It is probably cossyrite, as suggested by Rosenbusch, or possibly kaersutite, which has been found on Linosa. The latter is suggested by its pure brown color, without the reddish tinge so characteristic of cossyrite, and the nearly or quite parallel extinction of the small prisms in some specimens from Montagna Grande. The hornblende frequently surrounds and is later than some of the groundmass feldspars, while the pyroxene belongs to an earlier period of crystallization.

No magnetite is present in the groundmass of any of my specimens, but flakes of orange or blood-red hematite occur in some cases, which do not seem to be secondary. A little quartz may be detected in some cases as an interstitial residuum, but its amount is small.

Hyaline facies.—A specimen from the surface of a flow at Costa Zichidi, which is somewhat vesicular, is different from the others. In thin section are the usual feldspar phenocrysts, with rounded ones of red-brown cossyrite, a few of aegirite-augite, but none of augite. The groundmass consists largely of a pale yellowish glass, containing minute laths of feldspar. This glass is thickly crowded with peculiar dendritic growths of a deeper brown color which often assume a globular form from 0.2 to 0.5 mm. in diameter, and again larger irregular areas. Feldspar phenocrysts usually form the nucleus of these. They are made up of small grains seldom more than 0.01 mm. in diameter, either equant or elongated.

Toward the center of the spherulites the grains are thickly crowded, but they separate at the borders, which consist of small, irregular, radially divergent tongues and processes. The grains are light yellow in color with rather high birefringence, the areas showing a faint aggregate double refraction. Their extremely small size makes optical determination difficult, but they are probably an aegiritic augite.

Chemical composition.—Analyses were made of a specimen from a massive flow near the base of the southwest scarp of Montagna Grande, below Rione Miliac, of one from the crater of Monte

Gibelé obtained from Mr. Butler, and of one from the top of Costa Zichidi. Two by Foerstner are also given, one of the Montagna Grande rock and one of a flow at Porto Scauri.

ANALYSES OF TRACHYTE, GIBELE TYPE

(GIBELAL NORDMARKOSE)

	A	B	C	D	E	Aa	Ba	Ca
SiO_2	63.43	63.30	65.27	61.47	61.43	1.057	1.055	1.088
Al_2O_3	16.31	16.38	13.50	18.09	17.51	.160	.161	.132
Fe_2O_3	2.04	2.54	4.40	5.14	5.11	.013	.016	.028
FeO	3.14	2.36	2.52	3.06	2.30	.043	.033	.035
MgO	0.78	0.84	0.55	1.32	0.54	.020	.021	.014
CaO	1.70	1.62	0.85	3.00	2.45	.030	.029	.015
Na_2O	6.71	6.36	5.19	5.85	6.22	.108	.103	.084
K_2O	4.31	4.41	4.21	2.83	3.95	.046	.047	.045
H_2O+	0.18	0.83	1.98	n.d.	n.d.	....	....	....
H_2O-	0.26	0.10	0.14	n.d.	n.d.	....	....	....
TiO_2	1.19	0.71	1.09	n.d.	n.d.	.015	.009	.014
ZrO_2	0.06	....	....	....	....	....	....	....
P_2O_5	0.20	0.30	0.17	n.d.	n.d.	.001	.002	.001
SO_3	0.05	....	....	....	....	....	....	....
MnO	0.04	n.d.	0.27	n.d.	n.d.	.001	....	.001
BaO	0.05	....	....	....	....	....	....	....
	100.45	99.75	100.14	100.76	99.51	....	....	....

A. Below Rione Miliac, Montagna Grande. H. S. Washington, analyst.
B. Crater of Monte Gibelé. H. S. Washington, analyst.
C. Costa Zichidi. H. S. Washington, analyst.
D. Montagna Grande. H. Foerstner, analyst. *Zeits. Kryst.*, VIII (1884), 155.
E. Porto Scauri. H. Foerstner, analyst. *Zeits. Kryst.*, VIII (1884), 164.
Aa, Ba, Ca, mol numbers[1] of A, B, C, respectively.

The first two analyses are typical ones of distinctly sodic trachytes, slightly high in silica and with very high TiO_2, considering the salic characters of the rocks. They are remarkably alike and indicate a general uniformity in the flows of the Gibelé volcanoes, since A, coming from the foot of the Miliac scarp, must be considerably older than that from the Gibelé crater. The analysis of the Zichidi rock C resembles them in general features, but is higher in silica and ferric oxide and lower in alumina, magnesia, lime, and soda. Except for the lower soda it shows affinities toward the pantelleritic trachytes.

Foerstner's analyses cannot be regarded as very satisfactory, partly because of the non-determination of water, titanium, and

[1] This term is used instead of molecular ratios, following Wright and Van Orstrand (*Jour. Wash. Acad. Sci.*, III [1913], 233).

phosphoric oxides, and partly because of certain features which will be discussed later. They indicate, however, that the silica is probably lower in some of these trachytes than in my analyzed specimens.

The norms of A, B and C are given below:

	A	B	C
Q	3.90	5.58	17.10
Or	25.58	26.13	25.02
Ab	56.59	53.97	44.01
An	1.67	3.06	0.83
Di	4.83	2.48	1.94
Hy	1.59	1.96	0.50
Mt	3.02	3.71	5.57
Hm	....	....	0.64
Il	2.28	1.37	2.13
Ap	0.34	0.67	0.34
	99.80	98.83	98.08
Rest	0.64	0.93	2.12
	100.44	99.76	100.20

The magmatic symbol of A is I(II).5.1.4, that of B is I(II)."5.1"."4, and that of C is I(II).4.1.(3)4, using the notation recently proposed[1] to indicate the exact position of a rock magma in each division of the Quantitative System. The first two are in nordmarkose, in the persalane class but transitional toward dosalane, and hence are strictly to be called umptekose-nordmarkose, B not being as centrally placed in the other divisions as A. The excess of silica is so small as to be negligible. The Zichidi rock also falls in the same place as regards the class, but is in order 4, and its dosodic subrang is transitional toward the sodipotassic one, so that it is a liparose-kallerudose. Here the amount of normative quartz is notable, indicating its tendency toward the pantelleritic trachytes. It is to be noted that these trachytes (and the basalts) are the only Pantelleria rocks which show normative anorthite, so that, in spite of the presence of aegirite-augite, no acmite appears in the norm.

[1] Cross, Iddings, Pirsson, and Washington, *Jour. Geol.*, XX (1912), 554. I use the sign" to indicate that the position is intermediate but not transitional; that is between the central portion and the transitional border.

Mode.—Owing to the fine grain and complex texture of the groundmass, an exact estimate of the mode by microscopic measurement is impossible. When the norm is compared with the thin sections the amount of mafic minerals—pyroxene and hornblende—present is seen to be much larger than that of the normative pyroxene, while but a very small proportion of the normative ores is present in the mode. The mode is, therefore, somewhat abnormative, and it is clear that readjustments of the norm to estimate the mode must consist chiefly in combining the normative ores and pyroxenes with some silica and albite. These readjustments cannot be made with certainty, as two pyroxenes and a hornblende are present and their composition is unknown. But the amounts of these are small and, taking the thin sections into consideration, the following will represent fairly well the relative amounts of minerals present in my analyzed specimens from Montagna Grande A and Zichidi B.

	A	B
Quartz	3	13
Soda-microcline	83	70
Aegirite-augite	7	9
Hornblende	5	6
Magnetite	2	2
	100	100

These rocks are evidently slightly quartzose soda-trachytes, that of Zichidi containing so much quartz as to be transitional to the rhyolites. As this, however, is confined to the groundmass and is not at all prominent even there, it had best be classed with the trachytes. Their sodic character is chiefly evident in the feldspars, the augite is only slightly aegiritic, and the amount of soda-amphibole (cossyrite) very small, in these two latter respects differing from the next type.

Such alkali-trachytes have been called by Rosenbusch augite trachytes of the Ponza type. These of Pantelleria differ widely from the true Ponza trachytes, which Rosenbusch has described and specimens of which I have studied, in the total absence of biotite, either as such or as augite-magnetite aggregates represent-

ing original biotite crystals. The Ponza trachytes also differ chemically, especially in a higher potash content, judging from the only analyses of them which appear to have been made.[1] As occurrences of these sodic trachytes are becoming rather common, it might be well to call the true Ponza type, with biotite, *ponzite*, and those of the Pantelleria type, *gibelite*.

PANTELLERITIC TRACHYTE, ZENETI TYPE (ZENETAL GRORUDOSE)

Occurrence.—Rocks of this type, which are the "phonolites" of Foerstner, form flows seen in the lower portions of the internal scarps of the large, first-period caldera, notably at Costa Zeneti and Costa Zichidi. The type also occurs near the base of the more precipitous portions of the coast line, as near Punta Pozzolana and Cala Cinque Denti on the north, the coast from Punta Tracino to Punta Kharace on the east, and various stretches on the south and southwest. These coastal occurrences presumably are extensions of flows, the more central portions of which form the bases of the internal scarps, and rocks of this type may be regarded as the earliest known outpourings of the Pantelleria volcano.

Megascopic characters.—Rocks of this type are of a rather dark-gray color, and are usually compact, but slightly vesicular forms occur. The only phenocrysts visible are very small (1–2 mm.), glistening, white tables of feldspar, which are not conspicuous and make up less than 5 per cent of the mass. Here and there are equally small, black grains of augite, but the amount of these is quite negligible. The slightly brownish, dark-gray groundmass is dense and aphanitic, and in some specimens shows evidence of vitreous texture.

Microscopic characters (*Fig. 7*).—A brief description of the microscopic characters of some of these rocks has been given by Rosenbusch,[2] which coincides with my own observations and the few statements of Foerstner.[3]

The most prominent phenocrysts are soda-orthoclase, though they are not large or abundant. They are euhedral and tabular

[1] C. Doelter, *Akad. Wiss. Wien*, XXVI, 1875, pp. 148, 151.

[2] H. Rosenbusch, *Mrik. Phys.*, II, No. 2 (1908), pp. 839, 967, 1115

[3] H. Foerstner, *Boll. Com. Geol. Ital.*, 1881, p. 534

parallel to b (010), often showing Carlsbad twinning. A few small, euhedral, stout prisms of a rather bright-green, pleochroic aegirite-augite are also present, but no cossyrite phenocrysts were observed in my specimens or noted by Rosenbusch.

The groundmass is typically holocrystalline, and consists of numerous small prisms and anhedra of aegirite and hornblende in a colorless base of quartz and alkali-feldspar. Most of the aegirite is in the form of euhedral to subhedral prisms, never more than 0.2 mm. long and about 0.05 mm. thick, and usually much smaller, while small anhedral grains are also common. Its color is light green, extremely pale in the smaller individuals, and it is distinctly pleochroic, especially in the larger and more deeply colored individuals: $\mathfrak{a}$ grass-green, $\mathfrak{b}$ and $\mathfrak{c}$ lighter yellowish green. In the smaller and paler crystals the pleochroism is not well-marked. The deeper colored individuals show extinction angles $c \wedge \mathfrak{a}$ up to 24°, so that they are to be regarded as aegirite-augite, while in the small prisms the angle is much less and they may be considered to be almost or quite pure aegirite, though extremely light in color.

The hornblendes are by no means as well formed as the pyroxenes, and while many of them show a prismatic development, definite crystal faces are lacking, and many individuals are small, anhedral grains. Cleavage is not developed. The color is a deep chestnut brown and the mineral is highly pleochroic, an almost opaque brown and a light hair-brown. Between crossed nicols this hornblende often shows a peculiar, brilliant, copper color. This hornblende is presumably the cossyrite which forms phenocrysts in other Pantellerian lavas, as is suggested by Rosenbusch, though the pleochroism is somewhat different. A few small, anhedral grains of grayish blue, apparently arfvedsonitic hornblende, were seen in some sections, but their presence is exceptional.

The pyroxenes and hornblende are present in about equal amount, but there seems to be usually more of the former. They are often clustered in somewhat curved, narrow groups, the "dendrites" of Foerstner, which produce what might be called a wreath texture. The colorless base, seen between crossed nicols and

rather high powers, resolves itself into an aggregate of very small alkali-feldspar individuals, which vary in form from euhedral prisms to anhedral grains, imbedded in an interstitial cement of quartz. This last is often micropoikilitically developed,[1] areas with uniform extinction inclosing the small feldspars. This quartz is doubtless the mineral called nephelite, unequivocally by Foerstner and doubtfully by Rosenbusch, but which the large

ANALYSES OF PANTELLERITIC TRACHYTE

(ZENETAL GRORUDOSE)

	A	B	Aa	Bb
SiO_2	64.54	63.77	1.076	1.063
Al_2O_3	11.49	11.18	.113	.110
Fe_2O_3	5.14	5.02	.032	.031
FeO	2.99	2.58	.042	.036
MgO	0.89	0.51	.022	.013
CaO	0.64	1.37	.012	.025
Na_2O	5.46	5.55	.089	.090
K_2O	4.66	4.35	.050	.047
H_2O+	1.11	2.72	....	....
H_2O-	2.12	1.28	....	....
TiO_2	0.90	0.94	.011	.012
ZrO_2	0.08	....	....	....
P_2O_5	0.16	0.14	.001	.001
O_3	0.17	....	....	....
MnO	0.13	0.26	.002	....
	100.48	99.67		....

A. Base of Costa Zeneti. H. S. Washington, analyst.
B. Base of Punta Pozzolana. H. S. Washington, analyst.
Aa. Mol number of A. Ba. Mol number of B.

amount of free silica present in the norm shows cannot exist in the rock. Biotite is not present and no grains of magnetite were seen.

Hyaline facies.—A specimen of a hyaline facies of this type merits brief description. It forms a flow at sea-level at Punta Pozzolana.[2] It is compact, very dark grey, and with very few feldspar phenocrysts visible. In thin section these feldspars show no feature worthy of special note, and phenocrysts of aegirite-augite and hornblende are extremely rare. The groundmass is

[1] Cf. P. Geijer, *G. För. Stockh. Förh.*, XXXIV (1913), 51.

[2] At Punta Pozzolana I found no rock corresponding to the "trachydolerite" mentioned by Prior from this locality.

dohyaline and hyalopilitic, composed of a colorless or slightly brownish glass thickly felted with minute, slender, prismatic microlites of an almost colorless mineral, which is most probably an aegiritic pyroxene. There are also some minute laths of alkali feldspar, but not a trace of hornblende could be detected in the groundmass.

Chemical composition.—Two analyses were made of this type, and are given in the annexed table.

The rocks are distinctly higher in silica and ferric oxide and lower in alumina and soda than the preceding type, lime being lower in the main occurrences, and ferrous oxide, magnesia, potash, and titanium about the same. Foerstner (p. 534) gives a partial analysis of a Zeneti "phonolite"; $SiO_2=67.8$, $Na_2O=6.0$, $K_2O=3.8$. The high silica here is probably approximately correct, and is significant.

	A	B
Q	15.12	14.34
Or	27.80	26.13
Ab	33.01	33.01
Ac	11.55	12.47
Di	1.76	5.20
Hy	3.38	1.42
Mt	1.62	0.93
Il	1.67	1.82
Ap	0.34	0.34
	97.25	95.76
Rest	3.48	4.00
	100.73	99.76

The two rocks fall well within the subrang grorudose, II.4.1.3, though that of Punta Pozzolana is intermediate toward pantellerose, II.4.1.4. The chief interest of these norms lies in the fact that, in spite of the dominance of soda over potash shown in the analysis, the rocks are sodipotassic in their classificatory position. This is due to the small amount of alumina which necessitates the formation of femic acmite. The amount of alumina is too high, or that of soda too low, to permit of the formation of normative sodium metasilicate, which we shall meet with in the pantellerites.

Mode.—The groundmass is too fine grained, and the texture too confused, to permit of satisfactory measurements by Rosiwal's method of the relative amounts of the constituent minerals, but a recalculation from the norm, taking the thin sections into consideration, yields the following mode for the Zeneti trachyte:

Quartz	15
Soda-microcline	63
Aegirite-augite	12
Hornblende	10
	100

These trachytes are in many ways intermediate between the Gibelé trachytes and the pantellerites, so that the name of pantelleritic trachyte is applicable to them.

COMENDITE, NERA TYPE (NERAL GRORUDOSE)

Occurrence.—Flows of this rock—the "white liparite" of Foerstner—form sheets above those of the preceding type. They are met with at various points along the inner scarp of the caldera wall, notably at Cuddia Nera, where two superposed flows are seen, the upper being platy in structure and the lower distinctly columnar and the rather narrow columns often curved. They are capped by a thin sheet of the green pantellerite, next to be described. The type also occurs in the scarp of Costa Zichidi, on the west side of the Val di Monastero, and on the southeast side of the Valle Silhoumen, according to Forestner, though I did not see it here. Foerstner mentions it at the so-called Polveriera, the ancient citadel of Cossyra, southeast of the town, but probably terracing for vineyards has since covered the exposure as I observed here only basalts from the Sant' Elmo flow. Along the steep parts of the coast flows of this rock are seen, occurrences being at Punta Pozzolana, Cala Cinque Denti, and Cala Porticello. At the first of these the rock is rather tuffaceous, is covered by a yellowish pantelleritic tuff, and overlies a flow and scoria bed of black and green pantellerite, while at the sea-level is the vitrophyric zenetal grorudose described above. This type is briefly described by Rosenbusch.[1]

[1] H. Rosenbusch, *op. cit.*, p. 839.

Megascopic.—The rocks are compact and generally a very light gray, almost white, though a flow at Cuddia Nera is light pinkish through weathering; small phenocrysts of feldspar are numerous, with fewer of black hornblende and augite. The groundmass is very fine grained, somewhat dull, and phanerocrystalline.

Microscopic.—The largest phenocrysts are of soda-orthoclase, which are tabular parallel to *b* (010), and are like those already described. More interesting are those of hornblende which form not more than about 2 per cent of the rock. These are euhedral to subhedral, slender prisms, about 0.5 mm. long by 0.2 mm. thick. They have the faces *m* (110) and *b* (010) well developed, but no terminal planes. The prismatic cleavage is good. When these phenocrysts occur in the groundmass they are almost invariably surrounded by a narrow border of finely granular hornblende of somewhat lighter color, which is absent from the few included in feldspar phenocrysts.

The color of the hornblende is a rather dark chestnut brown, without the tinge of red which is so characteristic of the cossyrite of the various types of pantellerites. The pleochroism is very strong; $\mathfrak{r}$ and $\mathfrak{b}$ dark brown, or almost black, $\mathfrak{a}$ light yellow brown. It was difficult to determine the extinction angle accurately owing to the intense absorption, but values of $\mathfrak{r} \wedge c$ up to 20° were observed. Though the pleochroism differs from the normal cossyrite, the other characters, as well as the chemical composition deduced from the norm, show that this hornblende is a cossyrite and not a kaersutite which it somewhat resembles.

A few subhedral phenocrysts of a bright-green, slightly pleochroic aegirite-augite are present, and in a few sections rare anhedral olivine phenocrysts.

The groundmass is holocrystalline and is mostly composed of alkali-feldspar and quartz. The former is usually in the form of minute tables, giving rise to lath-shaped sections, though some anhedral grains occur. The quartz appears as small patches, about 0.1 to 0.2 mm. in diameter, usually irregular in outline but sometimes roughly rounded, which include feldspar grains microkoikilitically. Scattered abundantly through this quartz-feldspar

base are very small crystals of green aegirite-augite and the pleochroic brown hornblende, the latter being more abundant than the former. Both of these mafic minerals form highly irregular shreds and anhedra and are seldom if ever prismatically developed, nor do they occur in the wreathlike aggregates so characteristic of the preceding type. No magnetite is to be seen in any of the specimens nor did I see the biotite mentioned by Rosenbusch.

Chemical composition.—An analysis was made of the comendite which forms the lowest, columnar flow at Cuddia Nera, this being the freshest and that which best shows the brown hornblende. An analysis of a "liparite" from Cala Porticello by Foerstner is also given, but it is very doubtful if it is of the same type as it differs much in chemical composition and he gives no description.

ANALYSES OF COMENDITE, NERA TYPE

(NERAL GRORUDOSE)

	A	B	Aa
SiO_2	72.21	67.18	1.204
Al_2O_3	9.72	14.18	.096
Fe_2O_3	3.26	4.00	.020
FeO	1.07	2.48	.015
MgO	0.29	0.34	.007
CaO	0.82	2.78	.014
Na_2O	4.42	5.89	.071
K_2O	4.98	4.01	.053
H_2O+	1.96	n.d.	.....
H_2O-	0.24	n.d.	.....
TiO_2	0.62	n.d.	.008
P_2O_5	0.10	n.d.	.001
MnO	0.05	n.d.	.001
	99.74	100.86	.....

A. Lowest flow, Cuddia Nera. H. S. Washington, analyst.
B. "Liparite," Cala Porticello. H. Foerstner, analyst. *Zeits. Kryst.*, VIII (1884), 133.
Aa. Mol number of A.

This type differs from those described previously in the high silica, which is the highest found by me in any rock of the island. The predominance of ferric over ferrous oxide may be noted, and the small amounts of magnesia and lime. This rock is also the only one analyzed by me which shows a greater percentage of potash than of soda, though molecularly the latter is present in greater quantity. Foerstner's partial analysis[1] is of interest in

[1] *Boll. Com. Geol. Ital.*, 1881, p. 535.

this connection: $SiO_2=73.1$, $Na_2O=2.5$, $K_2O=5.0$. This rock from the Polveriera shows about the same amounts of silica and potash as that from the Cuddia Nera, but soda is somewhat lower, though in both the percentage of potash is greater than that of soda, and molecularly they are present in about equal amount. The distinctly high potash is noted by Foerstner as a character of the rock type.

Norm.—The norm of the Cuddia Nera rock is as follows:

	Norm
Q	31.14
Or	29.47
Ab	22.01
Ac	9.24
Ns	1.10
Di	2.57
Hy	0.46
Il	1.22
Ap	0.34
	97.55
Rest	2.24
	99.74

The type falls within the dosalane class but is transitional to persalane, and is nearly on the border of order 3. The rang is decisively peralkalic, no salic lime being present, since acmite exists in the norm, and the subrang is also clearly sodipotassic. It is therefore in (I)II, (3)4.1.3, so that the type should be called a varingose-grorudose. It will be seen that acmite constitutes the greater part of the femic minerals, and the presence of sodium metasilicate in small amount is to be noted as this is characteristic of the pantellerites, being correlated in the mode with the presence of cossyrite.

Mode.—Through the presence of the hornblende the mode is somewhat abnormative. From recalculation of the norm and study of the thin sections it may be expressed approximately as follows, the cossyrite being assumed to have the composition of that analyzed by Dittrich:[1]

[1] J. Soellner, *Zeits. Kryst.*, XLVI (1909), 540.

Quartz	30
Soda-microcline	51
Cossyrite	12
Aegirite-augite	7
	100

Though the type very closely resembles the pantellerites, yet it seems advisable to follow the suggestion of Rosenbusch and call these rocks comendites, partly because of the very high silica, partly because of the high potash, and partly because of the megascopic characters and the microscopic texture of the groundmass.

AEGIRITE PANTELLERITE, SANTELMO TYPE (SANTELMAL GRORUDOSE)

Occurrence.—Lavas of this type (the "crystalline pantellerite" of Foerstner) are abundant on the island. In the north it forms flows from Monte Sant' Elmo, an area to the south of Monte Gelkhamar, and a somewhat more extensive one from near Cuddia Bonsulton northeasterly to Costa Zeneti and Cuddia Nera (forming the upper part of these), Rione Khadingia, and beyond to the coast near Punte Pozzolana and Karuscia. In the south and southeast it constitutes the mass of Cuddia Attalora and the slopes from Cuddie dietro Isola and Serra Ghirlanda to the sea. As noted above the flows of this pantellerite were the last from the early volcano, before the great caldera-forming eruption. These lavas are often accompanied by yellow tuffs. Flows of this type are generally pahoehoe, and in places the lava is made up of mingled streaks of this and the succeeding type.

Megascopic characters.—These lavas are often platy, generally compact, but again somewhat vesicular. The type is distinctly but finely porphyritic. The aphanitic, dull, and apparently cryptocrystalline groundmass is of a light yellowish-green color, which varies somewhat in different specimens. Through this are sprinkled many small (1–3 mm.), glistening, white feldspar phenocrysts, and few smaller stout prisms of black pyroxene and hornblende. Some of these are also to be seen in the crevices and vesicles, with occasional small tables of tridymite.

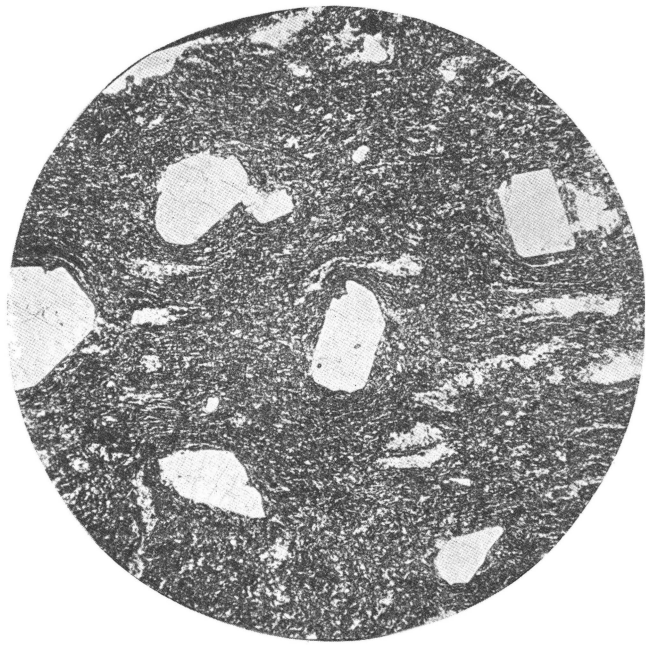

FIG. 8.—Aegirite pantellerite, Costa Zeneti. × 20

FIG. 9.—Hyalo pantellerite, Khagiar. × 20

Microscopic characters (*Fig. 8*).—The pantellerites of Pantelleria have been described in great detail by Rosenbusch,[1] who devotes especial attention to this type. Except for some minor details my observations fully bear out his descriptions.

The soda-microcline phenocrysts are not numerous in the sections. In general they are thick, tabular parallel to *b* (010), and euhedral, but are often fragmentary. They show no microcline or perthite structures and no albite twinning lamellae, but Carlsbad twins are frequent. Inclusions are rare.

In most of the specimens cossyrite phenocrysts are fairly common, while in others they are wholly wanting. They are stoutly prismatic and vary from 0.2 to 0.4 mm. in length. Originally euhedral, most of them show rounded outlines, especially at the terminations, and some are thus reduced to ovoidal forms. This is probably due to resolution by the magma, as suggested by Rosenbusch. Their color is a very deep reddish brown, with internal pleochroism; **r** brownish black, **b** deep chestnut brown, **a** red brown. A few small phenocrysts of a pleochroic, grass-green aegirite-augite are present. Magnetite grains are wholly absent, but there are a few zircons. I could find none of the olivine or apatite mentioned by Rosenbusch.

This rock type has a very peculiar and highly characteristic groundmass. Under low powers it is light, yellowish white and almost opaque through the abundance of patches and streaks of a dustlike substance, which commonly show a well-developed flow texture. This invariably occupies most of the section, and in the narrow interstices is a colorless substance with feeble, diffuse birefringence.

Under high powers the opaque substance is resolved into a felt of extremely minute, transparent, nearly colorless, prismatic microlites. These must be considered to be aegirite (as suggested by Rosenbusch), though their extreme tenuity renders determination of their optical characters very difficult. It is, of course, to the presence of this aegirite felt that the greenish color of the rock is due. No cossyrite or other hornblende was observed as a groundmass constituent. The colorless base is now seen to be generally holocrystalline, and formed of an intimate mixture of very minute

[1] H. Rosenbusch, *op. cit.*, pp. 852–54.

grains of feldspar and quartz, though colorless glass is present in small amount in some sections.

Pantellerite pumice.—With this type of pantellerite may be briefly described a pumice which covers a considerable area near the center of the island, about the summit of Montagna Grande and Cuddia Mida, between Monte Gibelé and Serra Ghirlanda, and in isolated patches elsewhere. It is whitish or cream colored, becoming a brownish yellow on wetting; highly vesicular, floating easily on water. Equant phenocrysts of alkali feldspar (2–5 mm.) are rather abundant, but none of mafic minerals. A flow texture is usually well developed.

In thin section this pumice is seen to be perhyaline. A few of the feldspar phenocrysts, and still fewer and smaller ones of aegirite-augite are present. The glass base is clear and colorless, carrying only extremely small amounts of "dust" and very rare microlites of feldspar and pyroxene. No hornblende is present.

Chemical composition.—Two analyses of this type of pantellerite, and one of the pumice were made. With them are given two by Foerstner and one by Abich of pumice.

These are all consistently higher in silica and ferric oxide, and lower in alumina, lime, and magnesia, than the trachytes described previously. The only difference of note between my two analyses of the type is the alumina, the higher figure in B being partly compensated for by the slightly higher iron oxides of A. Otherwise they are almost identical. It will be observed that TiO_2 is high for such silicic rocks. Attention must be called here to the relation of the iron oxides, the percentage of Fe_2O_3 being much higher than that of FeO in both. The analysis of the pumice is closely like the others, though lower in silica, and the proportion of ferric oxide is greater. It is chiefly on this account and because of the colorless glass that it is placed with the Santelmal type. The analyses of Foerstner are unsatisfactory in their incompleteness, and also seem to suffer from the usual systematic errors. It will, however, be observed that his iron oxides, though higher than mine, show much more Fe_2O_3 than FeO. While the analysis of Abich is, of course, unsatisfactory according to modern standards, yet, considering its date, it is very creditable, the alkalies alone being improbable.

ANALYSES OF AEGIRITE PANTELLERITE

(SANTELMAL GRORUDOSE)

	A	B	C	D	E	F	A*a*	B*a*	C*a*
SiO_2	70.14	69.79	67.32	70.30	67.48	68.11	1.169	1.163	1.122
Al_2O_3	8.61	11.91	9.55	6.32	9.70	8.21	.084	.117	.094
Fe_2O_3	6.01	5.35	6.73	9.23	7.42	8.23	.038	.034	.042
FeO	2.73	1.43	0.81	1.40	2.21	....	.038	.020	.011
MgO	0.20	0.25	0.20	0.89	0.77	0.37	.005	.006	.005
CaO	0.45	0.25	0.20	0.84	1.45	0.14	.088	.004	.004
Na_2O	5.44	5.66	5.71	7.70	7.21	8.32	.088	.091	.092
K_2O	4.20	4.59	4.48	2.50	2.94	1.60	.045	.049	.048
H_2O+	0.35	0.17	3.15	0.82	0.96	1.73	....	....	....
H_2O-	0.17	0.04	0.49	n.d.	n.d.	....	....	....	....
TiO_2	0.86	0.89	0.59	n.d.	n.d.	1.23	.011	.011	.007
ZrO_2	0.14	....	....	....	....	....	....	....	....
P_2O_5	0.12	0.13	0.08	n.d.	n.d.	n.d.	.001	.001	.001
SO_3	0.06	....	....	....	....	....	....	....	....
MnO	0.38	0.20	0.24	n.d.	n.d.	Cl= 0.70	.005	.003	.003
BaO	none	....	....	....	....	CH_4 = 0.66	....	....	....
	99.86	100.66	99.55	100.00	100.14	99.20	....	....	....

A. Monte Sant' Elmo. H. S. Washington, analyst.
B. Costa Zeneti. H. S. Washington, analyst.
C. Pumice. Rione Buccarame. H. S. Washington, analyst.
D. Khartibugal. H. Foerstner, analyst. *Zeits. Kryst.*, VIII (1884–), 173.
E. Monte Sant' Elmo. H. Foerstner, analyst. *Zeits. Kryst.*, VIII (1884–), 186.
F. Pumice of Pantelleria. H. Abich, *Vulk. Ersch.*, 1841, Taf. III.
A*a*. Mol numbers of A. B*a*. Mol numbers of B. C*a*. Mol numbers of C

The norms of the first three rocks are as follows:

	A	B	C
Q	27.60	21.78	22.44
Or	25.02	27.24	26.69
Ab	20.44	35.63	24.10
Ac	17.56	10.63	19.40
Ns	1.34	....	0.49
Di	1.21	....	....
Hy	4.10	0.60	1.03
Mt	....	2.09	....
Il	1.67	1.67	1.42
Hm	....	0.32	....
Ap	0.34	0.34	0.34
	99.28	100.30	95.91
Rest	0.72	0.21	3.64
	100.00	100.51	99.55

The Sant' Elmo pantellerite, therefore, falls in varingose, II.3(4).1.3, owing to the large excess of silica, but transitional to

grorudose, while the other two fall well within grorudose, II.4.1.3, B being intermediate toward liparose and pantellerose. Acmite predominates strongly among the femic minerals, and the amount of sodium metasilicate is very small or nothing, in which respect this type of pantellerite differs from that next to be described.

Mode.—Owing to the fineness of the grain the mode cannot be determined by optical means but can be recalculated from the norm, the same assumption being made as to the cossyrite as before.

A		B	
Quartz	28	Quartz	20
Or_5Ab_4	45	Or_4Ab_5	63
Aegirite	17	Aegirite-augite	14
Cossyrite	10	Cossyrite	3

This type, being holocrystalline, may be regarded as typical pantellerite, the cenotypal equivalent of Brögger's grorudite, the analyses of which are closely similar.

HYALO-PANTELLERITE, KHAGIAR TYPE (KHAGIARAL VARINGOSE AND GRORUDOSE)

Occurrence.—This type is, in general, later than the preceding, belonging to the last period of the second phase after the tilting of the Montagna Grande block and before the eruption of basalts. In certain localities, as at Sant' Elmo, Cuddia Nera, and, in the south of the island, flows of the Santelmal type show streaks and patches of this glassy black type. The cones and flows of this type are found around the tilted Montagna Grande block, at Cuddie Randazzo and Gelfiser, with their respective great flows, at the north, Gelkhamar and Sciuvechi at the northwest, the two small Monti Gibile to the west, Fosso del Russo and the lavas of Rione Benimingallo to the south, and those of Rioni Mueggine and Khamma to the east. These lava flows are of the *aa* type, the blocks being generally angular.

Megascopic characters.—The specimens from most of the occurrences are very uniform. They are black, highly vitreous rocks, composed of a pure black, generally lustrous, glass groundmass, which in some specimens is locally slightly iridescent due to incipient alteration. In the specimen from Cantina Ziton the glassy groundmass is dull and somewhat waxy in luster. This

glass is very thickly sprinkled with small (1–3 mm.), rectangular, nearly equant phenocrysts of white glistening feldspar, which do not show any flow arrangement. They are in some cases so abundant as to be present in almost as great amount as the glass, but typically the rock is dopatic. A few perpatic forms were seen—black obsidians with very rare and small feldspar phenocrysts. These pure obsidians do not seem to form flows, but occur as blocks in the yellow pantelleritic tuffs. In all the specimens examined by me this black glass is brownish in thin edges, and I saw none of the green glass noted by Rosenbusch and Foerstner.

Microscopic characters[1] (*Fig. 9*).—The numerous soda microcline phenocrysts are mostly euhedral, in stout prisms parallel to *c* or tables parallel to *b* (010), but a few are rounded as by magmatic corrosion and some are fragmentary. They are usually quite free from inclusions, but a few contain minute crystals of aegirite-augite or cossyrite. Phenocrysts of two kinds of pyroxene are present, both in very small amount. One is an almost colorless or very pale greenish-gray diopside; the other a bright grass-green, distinctly pleochroic aegirite-augite. Both occur as stout prisms, but subhedral with rounded edges, and the former is likely to be much corroded. The cossyrite phenocrysts are more abundant than those of pyroxene and resemble those of the preceding type. No arfvedsonite was seen and lime-soda feldspars and magnetite grains are wholly absent. Olivine is also wholly wanting, except in a specimen from Cantina Ziton, from a flow south of, and apparently from, Fosso del Russo. Olivine phenocrysts (about 2 per cent) occur in this in small euhedral or subhedral, slightly corroded crystals, carrying a few magnetite inclusions. No cossyrite occurs in this rock.

The groundmass is highly vitreous, the glass being brownish, never greenish in my specimens. In most specimens this glassy groundmass is dohyaline, small prisms of alkali-feldspar, with fewer of cossyrite and augite, being abundant. A flow texture is always well marked, shown by the fluidal arrangement of the microlites, as well as by streaks of more or less crystalline groundmass, some of which are almost holocrystalline and correspond to the groundmass of the Santelmal type.

[1] Rosenbusch describes this type with the preceding (*op. cit.*, p. 852).

The specimen from Cantina Ziton has a perhyaline groundmass —an almost colorless glass, slightly mottled with "dust" but free from microlites, spherulitic through the presence of yellow-brown cumulites, which are almost opaque and without action on polarized light. These are sometimes isolated and globular, and elsewhere in streaks with marked flow texture. They resemble the spherulites of some Hungarian liparites.

The obsidian is an almost absolutely pure, perfectly clear, light-brownish glass, less than 1 per cent of crystals being present, very small euhedra of alkali-feldspar and rare augite microlites, but no cossyrite. No perlitic cracks are seen in these or any of the glassy groundmasses.

Chemical composition.—Four analyses by myself and four by Foerstner are given:

ANALYSES OF HYALOPANTELLERITE

(KHAGIARAL VARINGOSE-GRORUDOSE)

	A	B	C	D	E	F	G	H	Aa	Ba	Ca	Da
SiO_2	69.91	66.07	69.33	67.85	69.61	68.75	68.33	67.89	1.165	1.101	1.156	1.131
Al_2O_3	8.58	11.74	8.62	12.87	8.02	5.91	10.94	11.53	.084	.115	.084	.126
Fe_2O_3	1.81	2.05	2.65	1.84	7.17	5.81	3.74	4.51	.011	.013	.017	.012
FeO	5.86	5.88	5.52	4.54	2.83	5.33	5.41	4.52	.082	.082	.076	.063
MgO	0.28	0.13	0.52	0.30	0.65	0.08	0.16	0.62	.007	.003	.013	.008
CaO	0.33	0.46	0.52	0.17	0.88	2.11	1.36	1.51	.006	.008	.009	.003
Na_2O	6.41	6.89	4.78	6.03	7.47	7.52	7.09	5.79	.103	.111	.077	.097
K_2O	4.71	4.80	4.71	4.83	2.88	4.28	4.08	3.71	.050	.051	.050	.051
H_2O+	0.22	0.43	2.35	0.13	0.74	n.d.	n.d.	0.33	....	....	....	....
H_2O-	0.13	0.03	0.27	0.02	n.d.	n.d.	n.d.	....	....	....	....	....
TiO_2	0.75	0.92	0.85	0.83	n.d.	n.d.	n.d.	n.d.	.009	.012	.011	.010
ZrO_2	....	0.12	....	....	....	....	....	....	....	....	....	....
P_2O_5	0.16	0.18	....	0.08	n.d.	n.d.	n.d.	n.d.	.001	.001	....	.001
SO_3	....	0.23	....	....	....	....	....	....	....	....	....	....
MnO	0.24	0.16	0.27	n.d.	n.d.	n.d.	n.d.	n.d.	.003	.002	.004	....
BaO	....	none	....	...	....	....	CuO= 0.25	....	....	....	....	....
	99.39	100.09	100.39	99.49	100.25	100.02	101.36	100.41	....	....	....	....

A. Gelkhamar. H. S. Washington, analyst.
B. Khagiar. H. S. Washington, analyst.
C. Cantina Ziton. H. S. Washington, analyst.
D. Obsidian. Costa Zeneti. H. S. Washington, analyst.
E. Khagiar. H. Foerstner, analyst. *Zeits. Kryst.*, VIII (1884), 173.
F. Cuddia Randazzo. H. Foerstner, analyst. *Zeits. Kryst.*, VIII (1884), 17[illegible].
G. Khania. H. Foerstner, analyst. *Zeits. Kryst.*, VIII (1884), 170.
H. Monte Sant' Elmo. H. Foerstner, analyst. *Zeits. Kryst.*, VIII (1884), 18[illegible].
Aa. Mol numbers of A. Ba. Mol numbers of B.
Ca. Mol. numbers of C. Da. Mol numbers of D.

These analyses resemble those of the preceding type in most respects, but differ in the higher soda and in the relative amounts of the iron oxides, ferrous oxide being here largely in excess of ferric, both in percentage and molecularly, though the sums of the two in both types remain about the same. Foerstner's analyses show the same relations to mine as in the previous cases, a tendency to lower alumina, and higher ferric oxide, magnesia, lime, and soda. Except in E his ferrous oxides are higher than ferric, or nearly so. I could detect none of the copper noted by him in any of my rocks.

Norms.—The norms of my analyses are as follows:

	A	B	C	D
Q	28.38	14.70	28.02	15.36
Or	27.80	28.36	27.80	28.36
Ab	17.82	33.54	17.82	39.30
Ac	5.08	6.01	7.85	5.54
Ns	7.08	4.15	3.17	1.22
Di	0.75	1.24	2.16	....
Hy	10.34	9.01	9.28	7.80
Il	1.37	1.82	1.67	1.52
Ap	0.34	0.34	....	0.34
	98.96	99.17	97.77	99.44
Rest	0.35	0.81	2.62	0.15
	99.31	99.98	100.39	99.59

These norms are noteworthy because of the large excess of soda, expressed as sodium metasilicate, over alumina and ferric oxide, which they show. This finds expression modally in the presence of cossyrite, and study of the thin sections shows that, in a general way, the amount of cossyrite present is correlated with that of sodium metasilicate in the norm. The analysis of cossyrite by Dittrich[1] yields nearly 9 per cent of sodium metasilicate, and it is also very high in ferrous oxide. These two factors determine the chief chemical differences between the two main types of pantellerite—the one with dominant aegirite and the other with dominant cossyrite among the mafic minerals.

These norms show that all the rocks are in dosalane. The Gelkhamar and Cantina Ziton rocks fall in varingose, transitional

[1] Cf. J. Soellner, *Zeits, Kryst.*, XLVI (1909), 539.

to grorudose, and the subrang is almost dopotassic through the very small amount of alumina present, II.3(4).1.(2)3. As this dopotassic subrang is as yet unknown, they may best be called grorudose-varingose. The others fall centrally in grorudose, II.4.1.3.

It will have been noted that none of the pantellerites analyzed by me fall in the subrang pantellerose, II. 4.1.4. This name was chosen for the subrang because of two analyses by Foerstner, which were then the only ones available.[1] As we shall see, however, these must be considered to be incorrect, and this case may serve as an example of the danger of basing rock names depending on chemical characters on any but reliable analyses. Further examples will be found in a forthcoming second edition of my *Collection of Rock Analyses*.

Mode.—The rock is so dominantly hyaline that the mode is indeterminate. It may be of interest to note, however, that if the lava had wholly crystallized the rocks would have had about the following composition: quartz 15 to 25, soda-microcline 45 to 55, cossyrite 15 to 25, aegirite or aegirite-augite 5 to 10. It is evident that a large proportion of the aegirite and cossyrite molecules would have been among the last to crystallize out. J. Soellner,[2] through an analysis by Dittrich, has shown that the olivine from this type of pantellerite is an almost pure fayalite, with FeO: MgO = 10:1. The analysis and the norm of the olivine-bearing pantellerite C confirm this, the ratio being 6:1.

It seems to be preferable to use the name hyalopantellerite for this type rather than to coin a new name. If the latter be deemed advisable that of *khagiarite* might be suggested.

BASALT (CAMPTONOSE)

Occurrence.—Basalts, all of which belong to the subrang camptonose (III. 5.3.4), are found only in the northwest corner of the island, being the products of eruption of the last phase of the volcano. They poured out from small cones—Cuddie Ferle, Bruciate, Monti, Rossi, Nera, and through the pantellerite on the

[1] Cf. H. S. Washington, *Prof. Paper U.S.G.S. 14*, 1903, p. 221.

[2] J. Soellner, *Zeits. Kryst.*, XLIX (1911), 144.

north slope of Monte Sant' Elmo—forming rather extensive flows from 2 to 5 meters thick, and accompanied by much scoria and ash. There are a few basaltic dikes cutting yellow pantellerite tuffs but these are of small size.

Megascopic characters.—These basalts present no unusual features and are of the common type, dark-gray to black rocks, aphanitic or nearly so, with few small phenocrysts of dark-green augite and sometimes yellow olivine and fewer of feldspar. Most of the specimens are slightly vesicular and scoriaceous *aa* flows are common. The scorias are generally black, but sometimes reddish. About Cuddia Ferle small, ovoidal or fusiform bombs are found.

Microscopic characters (*Figs. 10 and 11*).—The phenocrysts of feldspar are anhedral and either stoutly prismatic or tabular, parallel to *b* (010). Nearly all of them are of labradorite, about Ab_1An_1, with the usual twinning lamellae, and a few show a border of more sodic material. There are some phenocrysts of soda-microcline, especially in lava from Cuddia Ferle, which carry few inclusions, mostly of glass. Subhedra of colorless augite, often in clusters, are fairly common. Olivine phenocrysts are rather more common than those of augite in the Ferle basalt, but olivine is wanting in that from Sant' Elmo. It is highly euhedral, very fresh, with few inclusions of magnetite. The rock analysis and norm show that it is an olivine and not fayalite.

The groundmass is typically basaltic, composed largely of thin plates of labradorite, grains of colorless augite, and considerable magnetite. In the larger flows it is holocrystalline. No nephelite is to be found.

A dike of basalt which cuts the yellow pantellerite tuffs at the northeast end of Costa Zeneti merits a few words of description. It has an east-west trend, approximately radial toward Cuddia Ferle, which is about one and a half kilometers to the west. It is vertical, from 10 to 30 cm. wide, and has hardened and blackened the rather incoherent tuff for about 5 cm. on either side. The rock itself is jet black and aphanitic, very minutely vesicular, more coarsely so toward the borders, and is almost free from phenocrysts, very small (1–2 mm.) feldspars being sparingly present. In the section thin tables of labradorite are prominent, augite

FIG. 10.—Basalt, Cuddia Ferle. × 20

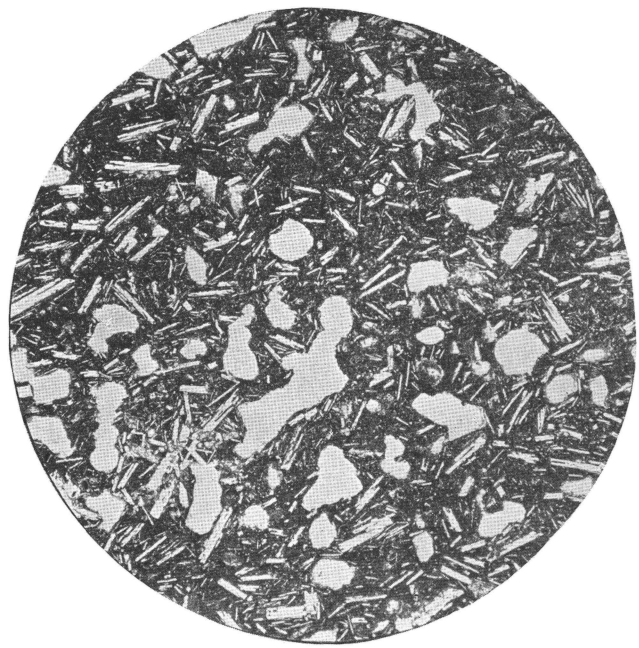

FIG. 11.—Basalt, dike, Costa Zeneti. × 20

anhedra are not common and there is very little olivine. These lie in a base of glass which, black under low powers, is seen under high to be thickly crowded with brown and black globulites. In this respect, as well as in the character of the feldspars, it is much like the basalts of the submarine eruptions of 1831 and 1891,[1] which it also resembles chemically.

Chemical composition.—Three analyses of these basalts, with two of the submarine lavas, and two by Foerstner, are given in the table.

ANALYSES OF BASALT

(CAMPTONOSE)

	A	B	C	D	E	F	G	A*a*	B*a*	C*a*
SiO_2	46.40	46.22	45.72	44.83	48.97	49.87	49.35	0.773	0.770	0.762
Al_2O_3	14.34	12.23	12.45	11.73	16.37	14.80	15.71	.141	.120	.122
Fe_2O_3	4.09	4.91	1.57	1.35	1.33	8.25	7.44	.026	.031	.010
FeO	8.22	7.71	12.01	11.79	8.56	6.88	6.96	.114	.107	.167
MgO	7.00	6.74	5.29	5.50	6.22	6.77	5.71	.175	.169	.132
CaO	9.85	9.86	9.58	9.63	7.49	9.36	9.80	.177	.176	.171
Na_2O	3.59	3.39	3.40	3.34	4.09	2.81	2.96	.058	.055	.055
K_2O	1.00	1.13	1.08	1.40	1.72	0.68	1.31	.011	.012	.011
H_2O+	0.14	0.17	0.40	0.81	0.38	0.45	0.49	....	....	....
H_2O-	0.08	0.05	0.01	0.10	0.08	n.d.	n.d.	....	....	....
TiO_2	4.54	5.68	6.43	6.88	3.95	n.d.	n.d.	.057	.071	.080
ZrO_2	none	....	....	....	....	....	....	....	....	....
P_2O_5	0.85	1.46	1.54	2.14	1.04	n.d.	n.d.	.006	0.010	.010
SO_3	0.12	....	....	....	....	....	....	....	....	....
MnO	0.25	....	0.16	0.20	0.06	n.d.	n.d.	0.003	....	0.002
NiO	....	....	0.15	....	0.08	....	....	....	....	....
BaO	0.09	....	....	....	....	....	....	....	....	....
SrO	0.03	....	0.03	....	....	....	....	....	....	....
	100.59	99.55	99.82	99.70	100.34	99.87	99.73	....	....	....

A. Cuddia Ferle. H. S. Washington, analyst.
B. Monte Sant' Elmo. H. S. Washington, *Q.J.G.S.*, LXIII (1907), 74.
C. Dike, Costa Zeneti. H. S. Washington, *Q.J.G.S.*, LXIII (1907), 74.
D Foerstner Volcano (1891). H. S. Washington, *Am. Jour. Sci.*, XXVII (1909), 145.
E. Graham Island (1831). H. S. Washington, *Am. Jour. Sci.*, XXVII (1909), 138.
F. San Marco. H. Foerstner, analyst. *T.M.P.M.*, V (1884), 393.
G. Cuddie Monti. H. Foerstner, analyst. *T.M.P.M.*, V (1884), 393.
A*a*, B*a*, C*a*. Mol. numbers of A, B, and C, respectively.

The analyses of the Pantellerian basalts are much alike, and except for the rather low silica and high titanium and phosphorus, are not specially noteworthy. The only marked difference is in the iron oxides. While the sum of both is about the same in all, in

[1] H. S. Washington, *Am. Jour. Sci.*, XXVII (1909), 131.

the flows A and B the molecular amount of FeO is about four times that of Fe_2O_3, but in the dike C it is seventeen. In this respect the dike basalt resembles the basalts of the two submarine eruptions D and E, the former close to the harbor of Pantelleria and the latter about 33 miles to the northeast. It will be seen that C and D are almost duplicates, while E differs considerably in the silica and other respects. These relations of the iron oxides give rise to the idea that the ferrous oxide has been prevented from oxidation in the dike and the submarine eruptions—a point which has been discussed in a previous paper.

Norms.—The norms of the Pantelleria basalts are as follows, those of the submarine ones having been given in the paper cited:

	A	B	C
Or	6.12	6.67	6.12
Ab	28.30	28.82	28.82
An	20.02	14.73	15.57
Ne	1.14	.....	.....
Di	18.81	19.54	18.77
Hy	.....	8.06	5.74
Ol	9.32	0.28	6.29
Mt	6.03	7.19	2.32
Il	8.66	10.79	12.16
Ap	2.02	3.36	3.36
Rest	0.46	0.22	0.69
	100.88	99.66	99.80

These norms place all three Pantellerian basalts in camptonose, III. 5.3.4, a subrang in which many basalts and gabbros fall. It will be noted that, in spite of the low silica, nephelite is not present in the norm, except to a slight extent in the Ferle rock, and it can hardly be said that these basalts have the trachydoleritic character assigned them by Rosenbusch (p. 1357). It will also be observed that these norms correspond with the microscopic characters, the Ferle rock carrying considerable olivine, which is wholly absent from the Sant' Elmo basalt.

Mode.—It is impracticable to estimate the mode by Rosiwal's method because of the fineness of the grain. Apart, however, from the small amount of alumina (to be taken from normative anorthite) which enters the augite the mode is essentially norma-

tive, and the modes of the two basalts of Ferle and Sant' Elmo may be roughly stated as follows, the orthoclase being reckoned in with albite. It is possible that the nephelite molecule of the norm exists as carnegieite in the feldspar.

	I		II
Ab_1An_1	50	Ab_3An_2	48
Nephelite	1	Augite	32
Augite	22	Ores	17
Olivine	9	Apatite	3
Ores	14		100
Apatite	2		
	100		